THE BEST SUPPLIER SELECTION BY USING ANALYTIC HIERARCHY PROCESS (AHP) AND FUZZY COMPREHENSIVE EVALUATION (FCE) METHODS: AN EXAMPLE OF A TURKISH LEATHER APPAREL COMPANY

AHP VE BULANIK KAPSAMLI DEĞERLENDİRME YÖNTEMLERİ İLE EN İYİ TEDARİKÇİ SEÇİMİ: BİR TÜRK DERİ FİRMASI ÖRNEĞİ

Pelin OFLUOĞLU[1], Nilay ÖRK[2], Mehmet Mete MUTLU[3], Turan ATILGAN[4*]

[1,4]*Ege University, Engineering Faculty, Department of Textile Engineering, 35040, Bornova, İzmir*
[2,3]*Ege University, Engineering Faculty, Department of Leather Engineering, 35040, Bornova, İzmir*

ABSTRACT

Today's tough competitive conditions require managing companies' supply chain management more effectively to protect the competitiveness in the field of leather apparel as in every sector. The selection of the most suitable suppliers for the company's expectations and criteria is an important decision problem in the management of this chain. In the scope of this study, a Turkish leather apparel company was selected and a field survey was carried out on leather supply by the participation of the purchasing managers of this company. Analytic Hierarchy Process (AHP) and Fuzzy Comprehensive Evaluation (FCE) methods were utilized for the analysis of the obtained data. Logical and consistent results were obtained and the most suitable supplier to the company criterion is determined by combining the advantages of both methods. Furthermore, some conclusions and recommendations for the company and the industry were manifested.

Keywords: Supplier selection, leather sector, apparel sector, AHP, FCE

ÖZET

Günümüzün zorlu rekabet koşulları her sektörde olduğu gibi deri konfeksiyonu alanında da firmaların rekabetçiliklerini korumaları amacıyla, tedarik zinciri yönetimlerini daha etkili bir şekilde yönetmelerini gerektirmektedir. Bu zincirin yönetilmesinde firmanın beklentileri ve kriterlerine en uygun tedarikçinin seçimi önemli bir karar problemi olmaktadır. Çalışma kapsamında, bir Türk deri konfeksiyon firması ele alınmış ve firmanın satın alma yöneticileri ile mamül deri tedariği üzerine bir saha araştırması yürütülmüştür. Elde edilen verilerin analizi amacıyla AHP ve Fuzzy Comprehensive Evaluation (FCE) yöntemlerinden faydalanılmıştır. Her iki yöntemin avantajları birleştirilerek, mantıklı ve tutarlı sonuçlar elde edilmiş ve firmanın kriterlerine en uygun tedarikçi belirlenmiştir. Ayrıca, firma ve sektöre yönelik çeşitli çıkarımlar ve önerilerde bulunulmuştur.

Anahtar Kelimeler: Tedarikçi seçimi, deri sektörü, hazır giyim sektörü, AHP, FCE

Corresponding Author: Turan Atılgan, turan.atilgan@ege.edu.tr.

INTRODUCTION

Leather products have been useful materials since the dawn of human history. In the tanning industry, raw skin is transformed into leather by means of a series of chemical and mechanical operations. Leather processing technology has evolved naturally from a traditional practice to an industrial activity (1).

Leather is a unique commodity that links the rural farmer to the fashion world. Leather as a natural material offers numerous advantages over synthetics, namely, aesthetic appeal, feel, texture, and breathability (2). Formerly leather products were used as a necessity for dressing but today they are a subject of consumption as ornament, prestige or social status, as well as they provide a natural look and cold protection.

Leather goods industry comprises sub-sectors of tanning and leather processing, leather goods, leather apparel, fur and footwear. Leather apparel industry is labour-intensive. However, when the input costs are investigated, it is seen that the cost of the leathers, which is the main input of the production as clothing, has the largest share. For example; leather jacket production requires numerous inputs. The major cost of a jacket, which is more than 74%, is the leather cost followed by the labour cost which accounts for about 21% (3). Also according to the study of production cost by Istanbul Leather and Leather Products Exporters' Association, which the cost structure of companies operating in the leather and leather products industry was surveyed, raw materials take the highest share among the cost factors of production, then comes the labour cost second (4). Therefore, additional effort on the supply and/or value chain of the leather processing is recommended.

Globalizing world, changing trade conditions, competitive market of today's and increasing consumer demands and expectations require companies to manage their supply chain management more effectively with each passing day. As it is known, today's consumers expect increasing variety of products scale, lower costs, higher quality and fast service quality from the companies which they are shopping from (5). This case works backwards in the supply chain management by creating a domino effect and also requires other companies to commit these criteria. Besides, supplier selection process brings a decision fact with multi-criteria; and also, different industries may have different requirements which causes different supplier selection criteria. Suppliers show different performance levels for each criterion. Whereat, supplier selection requires company managers to think comprehensive and work systematic.

The sustainability of a company's business becomes possible by building good relationships with other companies and effective supply chain management. According to Patton (6), evaluation and selection of a supplier constitute a main subject in purchasing process of the company.

When leather industry is considered in terms of general foreign trade scale of Turkey; it can be easily seen that: together with textile and apparel industries, it has foreign trade surplus. This helps, in general, decreasing the unemployment rate and increasing the wealth of the community. When these industries are evaluated all together, they cover more than 10% of the GUP (Gross Domestic Product) of Turkey and 16% of the added value of manufacturing industry. It's noted that these industries and related industries make major positive contributions to the economy of Turkey.

In consequence of hectic demands and suitcase trading from former Soviet Union Countries in 1990's, leather and leather products industry showed a major improvement in production and exportation. This process has led to the realization of large investments and therefore increased capacity of the industry (4).

The leather industry, which exported a total amount of 1.8 billion dollars in 2014, decreased to 1.5 million dollars (21.3%) in 2015 (7). The major problems of this decrease in export are political matters with Russia and internal problems of neighbouring countries. If problems continuing

in the country geography and on management of companies end, this industry, which has shown significant improvements in recent years, may become a major production and design centre of the world. Suitable supplier selection and cooperation take an important role in success of the companies in this industry. Therefore in this study, suitable supplier selection problem of a leather apparel company on purchasing leather at supply chain management was discussed.

Importance of Supplier Selection, Used Criteria and Methods

Finding suitable suppliers for company's demands and expectations is one of the basic requirements of an effective supply chain management. The subjects of supplier selection have been addressed in numerous national and international studies; because this issue has a great importance on maintaining activities and the survival of the company in long term. Studies conducted in various industries sought the solution of suitable supplier selection problem by using different criteria and methods. Dickson (1966), who put forward important ideas in this regard, has identified 23 criteria at his research which was carried out with 170 business managers on the purpose of evaluating the performance of suppliers for operations (8) and he has shed light for oncoming researchers about the supplier selection by his study (9, 10). According to this study; price, delivery and former performance of the supplier were determined to be the most important criteria.

Nowadays, it is seen that the priorities of the Dickson's 23 criteria were changed and new criteria were added according to developing new market requirements (8, 9). These 23 and newly added criteria can be seen in the literature in a compiled format by taking into account of researcher's aim, subject and on implemented industry (11, 12, 13). For example; Mokhtari et al. (5) utilized seven criteria in the supplier selection in Iranian textile industry and, Yang and Chen (14) utilized totally ten criteria which were based on qualitative and quantitative information in the IT sector.

After the determination of the supplier selection criteria, there comes the stage of decision making on an appropriate mathematical model for suitable supplier selection. There is no single method in this regard; so, many researchers sought most appropriate solution by using different methods or combinations of them. When the studies in the literature are investigated, it is seen that multi-criteria decision methods used in the supplier selection process are collected in five main groups: linear weighting, cost-based, mathematical programming, statistical methods and artificial intelligence (AI) expert systems. The methods based on artificial intelligence, consist in computer-aided systems that can be trained with previous data. It is seen that, these methods are often used to optimize supplier selection or decision of outsourcing (9). Another AI method that made a name frequently in recent years is fuzzy logic. This method which has attracted interest of many researchers, has also found an application area on supply chain (11, 12). Another method that was added to the literature as one of the branches of the fuzzy logic system is Fuzzy Comprehensive Evaluation (FCE) method.

In the literature; aforesaid method has found its uses in different industries because of the reason that it allows making analysis in the frame of various criteria and the usage of verbal and numerical judgments together in the evaluation of these criteria. The AHP and FCE methods are used together in these following researches: evaluation and selection of power supply projects (15); evaluation of a company's internal financial control (16); risk assessment in the supply chain (17); analysis of technical innovation skills of small and medium-sized enterprises (18); carrying out the risk assessment (19); analysis of product quality evaluation system (20); determining the most suitable supplier for the criteria on coal supplier selection (21); evaluation of a company's managers (22); determining the level of obesity in a city located in China considering the criteria that cause obesity (23).

The combination of these methods have also been used in the former studies based on the selection of suppliers for apparel companies. However, these studies have been found to be limited and open to new progress (24). Nevertheless, supplier selection studies based on the combination of these two methods in the field of leather are found to be lacking and have not been encountered. Considering this gap, it is thought that this study will contribute to the literature.

Briefly, fuzzy comprehensive evaluation method helps determination of which level is the predetermined judgment criteria for the factors that will be evaluated by considering the criteria hierarchy. To achieve this goal, the aim of the study and the criteria that affect the aim should be addressed as a system. Since AHP, from among methods which provides these systems, is often used; most studies which are based on FCE method as mentioned above, have been carried out based on FCE and AHP methods.

MATERIALS AND METHODS

This study was carried out in Orjin Leather Company which operates in Istanbul and expertized in production of leather apparel. The company which has begun operations in 1980 has realized its average annual production of 90,000 leather jackets with 290 employees today. In 2015, company's turnover was approximately 13 million Euros. The company, which makes production for export, has adopted a structure of world standards quality and high technology. In the context of this study, it was asked from purchasing executives of Orjin Leather to evaluate the main suppliers, from whom they supply the required leather materials for manufacturing, in the frame of the determined criteria and the evaluation scale.

Three authorities who perform on purchasing in this company were determined and the study was conducted by asking survey question to these people. For this purpose, the authorities have selected three suppliers and their evaluations were carried out taking into account these suppliers.

Evaluation of these suppliers which serve for maintaining the required leather material for this leather apparel company was targeted. To achieve this goal, the previous studies were investigated carefully and at the same time, the criteria hierarchy located below were established by considering the views and contributions of the academicians and industrialists who know this company and leather industry well (figure 1). As it can be seen from the figure, the criteria, taken into account in the supplier selection, were divided into four main and eleven sub-criteria. The main criteria consisted of product quality, price policy, delivery terms and reputation in the industry and the sub-criteria consisted of product properties, standards, production capacity, product price, payment options, distance of supplier to the company, delivery time, packing and transport properties, market recognition, warranty policy and after-sales service quality.
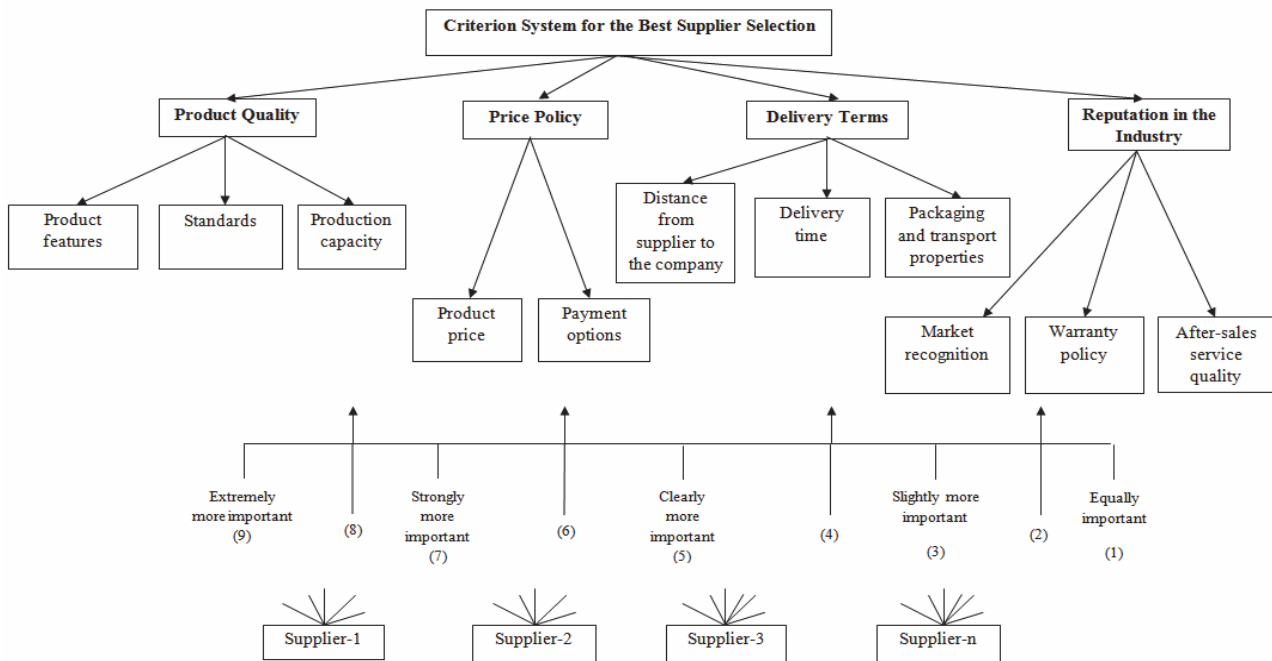

Figure 1. Hierarchical structure of the criteria to be taken into account in the selection of leather supplier

The first main criterion "Product quality" is about quality of the leather material during the process stage and final quality of the product at sale stage. Product quality criteria consists of "Product properties" criterion which enables assessment of suitability and diversity of leather properties such as colour, handle, touch, thickness, flexibility etc.; "Standards" criterion which includes standards and certificates that must be provided in order to sell the final product at national and international market; and "Production capacity" which is about suppliers to deliver the product in desired amount, specified quality and delivery time. The second main criterion "Price policy" consists of "Product price" which was determined for the materials by their suppliers and "Payment options" which includes financial payment options offered by the supplier.

The third main criterion "Delivery terms" consists of "Distance of supplier to the company" and "Delivery time", which are in close relationship with the delivery of existing and future orders in time; and "Packing and transport properties" which is intended to deliver the materials without damage, properly and completely. The fourth main criterion "Reputation in the industry" which was generated in order to measure the reliability and public image of the suppliers, consists of; "Market recognition" which affects important facts such as allying long-term partnerships and payment terms; "Warranty policy" which includes the legal liability concerning the product, assumed by the suppliers and provided to the commercial partner; "After-sales service quality" which includes work experience, approach and problem solving skills of the suppliers' employee who gets in contact with the purchasing company after the sale.

Studies based on supplier selection are implemented in the literature via various criteria and methods including both quantitative as well as qualitative data. Therefore, supplier selection process is a multi-criteria decision problem due to the need of assessment of numerous criteria. In this regard, the use of analysis techniques that reveal the relative priorities of the factors that play role in the analysis of the problem and ease the evaluation within the combination of all the related factors may have a strategic importance for the companies. Based on these reasons, Analytic Hierarchy Process (AHP) is determined as the first method utilized in the study. In order to fulfill this purpose, pair-wise comparisons of the selection criteria were performed to enable a detailed analysis of the criteria and also to reflect the opinions of the personnel performing the supplier selection process in a more reliable way.

In addition, companies usually face complex situations that involve multiple criteria which prevents evaluations within certain judgments in daily business life. Thus, methods that are only based on quantitative data and disable the personal perception and decisions affected by the previous experience and knowledge may not be enough to solve daily complex business problems. Therefore, fuzzy logic, one of the artificial intelligence approaches reflecting the subjective judgments as the numerical data and developed by Zadeh (25) is incorporated into the mathematical modeling part of the study. Considering that the evaluations regarding the supplier selection criteria often require non-

measurable subjective conclusions, the fuzzy logic system appears to be suitable for the study. Consequently, Fuzzy Comprehensive Evaluation Method (FCE) based on fuzzy logic is implemented and combined with AHP in the study. The relative importance weights of the supplier selection criteria used by the previously mentioned company are appointed by AHP. Afterwards, the method of FCE is implemented for the interpretation of the company's purchasing department employees' evaluations based on both the criteria and suppliers. The combination of these models improves accuracy and reliability of the study.

The following steps are followed within the framework of AHP:

(1) Determination of the hierarchical structure of the study problem

Firstly, the hierarchical model of the problem is determined in accordance with the supplier selection criteria defined for this study. The main target of "The most suitable supplier selection for a company operating in the leather sector" lies on the highest level in the hierarchy as "Level-1". The main four criteria contributing to the main target take place in the second level and eleven sub-criteria related to the main ones can be seen in the third level. The fourth level indicates the evaluation scale of the main and secondary criteria, while the fifth level shows the alternative suppliers that will be evaluated within the framework of main and secondary criteria based on the evaluation scale. The relative importance weights of the main and also secondary criteria are scored on a scale of 1-9. According to this scale the numerical ratings and verbal judgments accordingly are as follows:

1: Factor A is equally important to factor B,

3: Factor A is slightly more important than factor B,

5: Factor A is clearly more important than factor B,

7: Factor A is strongly more important than factor B,

9: Factor A is extremely more important than factor B,

2,4,6,8: Intermediate values

Finally, the fifth level indicates the alternative suppliers. The hierarchy mentioned is summarized and showed in figure 1.

(2) Formation of the pair-wise comparison matrixes

After creating the hierarchical model of the problem, the relative weight of the criteria form the hierarchy are indicated through judgment matrixes. Pair-wise relative weight determination method, developed by Saaty, is utilized to fulfill this purpose.

(3) Consistency tests of pair-wise comparison matrixes

If the random consistency proportion CR is less than 0.1, the consistency of the judgment matrix is favorable according to the literature. Therefore, the results will be reliable accordingly.

The steps followed within the framework of FCE are summarized below:

(1) Determination of the evaluation factor set

At this stage, the factor sets for the evaluation target are determined. This set is expressed as U={ $U_1, U_2,....,U_j$}, U_i (i=1,2,...,n). "n" defines the number of single factors within the same hierarchy.

(2) Determination of the factor weights

The relative importance weight of every single factors in the hierarchy is determined through the method of AHP. Weight set of the factors is defined as: A={a_1, a_2, a_3,...,a_n}. These weights are obtained after the normalization process, compatible with the following conditions (equation 1).

$$\sum_{i=1}^{n} ai = 1 \ , ve \ 0 < ai < 1 \tag{1}$$

(3) Determination of the evaluation set and standard membership degree of the evaluation set

Evaluation set, defined as V = {V_1, V_2, ..., V_m}, includes the entire possible judgment degrees, in other words the comments, for the evaluations. The standard membership degree set of the evaluation is expressed as: u={$u_1, u_2,...,u_m$}, u_i (i=1,2,...,m) and "m" defines the grade number of membership expressions.

(4) Establishing the single-factor fuzzy evaluation matrix (R) of the tested objects

Appraisals of the experts are expressed in terms of a fuzzy vector shown below. The appraisal set of R_i=($r_{i1}, r_{i2}, r_{i3},...,r_{im}$) can be considered as a fuzzy subset of V, where r_{im} is the fuzzy membership degree of appraisal of factor i to grade m which is expressed as follows in the equation 2 (26):

$$F: U \longrightarrow f(V) \ ; U_i \longrightarrow (r_{i1}, r_{i2}, r_{i3},...,r_{im)} \tag{2}$$

After normalizing the data obtained through the formulation above, the sum of all of the vectors become equal to one, $r_{i1}, r_{i2}, r_{i3},...,r_{im}$=1. Thus, single-factor evaluation matrix (R) is constituted by the appraisal results of single factor evaluation vectors in sum (figure 2).

(5) Calculating the fuzzy comprehensive membership grade set (B) of the factors and the overall comprehensive membership grade of the hierarchy

$$R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ r_{n1} & r_{n2} & \cdots & r_{nm} \end{bmatrix}$$

Figure 2. Notation of the single-factor evaluation matrix (R)

Fuzzy comprehensive membership set matrixes are obtained through the multiplication of the fuzzy matrixes formed for every secondary criteria subset with the standard membership degree of the evaluation set, expressed as B = R.u^T .

After obtaining the evaluation matrixes according to formula above, a more comprehensive evaluation grade is gained via the multiplication of the weight vectors of the factors with

these matrixes. The mathematical expressions of these statements are as follows (equation 3 and 4):

$U_m = A_n.B_n$,   n: Number of the main criteria   (3)

U= A.ū   ,   ū = ($U_1, U_2,...,U_n$)   (4)

(6) Reaching the final judgment

Within the framework of maximum membership function, the judgment grade with the maximum evaluation score is regarded as the final judgment and expressed as the corresponding evaluation statement in the evaluation set.

In this study, the steps defined above were performed for three different suppliers due to the need of evaluating three different suppliers within the same criteria and by the same buyers and the final judgment is reached subsequently.

DATA ANALYSIS AND RESULTS

The methods of AHP and FCE are used in combination in the selection process of the most suitable supplier for the company analyzed. The data obtained in accordance with the above-described method steps and the evaluations based on these data are summarized in this part of the study.

(1) Firstly, the evaluation factor set was determined in the frame of the methods. In other words, the hierarchical structure of the problem was established to enable the use of AHP. The factors that constitute this hierarchy is summarized in figure 1. Accordingly, the factors to be assessed are listed as follows:

U= {$U_1, U_2, U_3, U_4, U_5, U_6, U_7, U_8, U_9, U_{10}, U_{11}$}={Product features, standards, production capacity, product price, payment options, distance from supplier to the company, delivery time, packaging and transport properties, market recognition, warranty policy, after-sales service quality}

(2) The factor weights were obtained via pair-wise comparisons of AHP procedure and the average weights were calculated based on the decision makers' appraisals. Average weights of the factors are listed in the following table (Table 1). Additionally, CR values of the entire matrixes formed within the case study are highlighted in table 2. Because of the reason that CR<0.10 in all of these matrixes, the data can be regarded as valid and reliable.

(3) An evaluation set is defined by considering the judgment sets in the previous studies. The evaluation set of the study is as follows:

V={v_1, v_2, v_3, v_4}={Excellent, good, fair, poor}

These evaluation set members were assigned by the buying specialists of the company of Orjin to the suppliers in accordance with their performances based on the factors defined.

After gaining the comprehensive matrixes representing the fuzzy membership degrees of the factors, the next step requires to determine the comprehensive membership degree of the suppliers considering the factor weights. The procedure followed are shown below (figure 5).

Table 1. Factor weights obtained through AHP

Factor sets	Weight sets of the factors
A: Product quality, Price policy, Delivery terms, Reputation in the industry	**A=** (0.169, 0.158, 0.165, 0.507)
A₁: Product features, Standards, Production capacity	**A₁=**(0.549, 0.309, 0.142)
A₂: Product price, Payment options	**A₂=** (0.878, 0.122)
A₃: Distance from supplier to the company, Delivery time, Packaging and transport properties	**A₃=** (0.171, 0.618, 0.211)
A₄: Market recognition, Warranty policy, After-sales service quality	**A₄=** (0.110, 0.434, 0.456)

Table 2. CR values of the evaluation matrixes

Factor sets	CR values of the first decision maker's matrixes	CR values of the second decision maker's matrixes	CR values of the third decision maker's matrixes
A	0.0579	0.0579	0.0022
A₁	0.0237	0.0237	0.0015
A₂	0.0000	0.0000	0.0000
A₃	0.0025	0.0370	0.0019
A₄	0.0516	0.0000	0.0176

The membership degree set of the evaluation expressions above is as follows:

u={1/excellent, 0.8/good, 0.6/fair, 0.1/poor}

(4) Fuzzy matrixes of R were established in the light of the data based on the evaluations of the buying specialists. These matrixes were created by considering the secondary criteria related to their main criteria. Due to the need of evaluating three different suppliers, the following matrixes were established separately and the FCE steps were followed for three times accordingly. The normalized matrixes of the first supplier evaluation is indicated as an example, as shown below (figure 3).

(5) Fuzzy comprehensive matrixes were obtained via the multiplication of membership degree set of the evaluation expressions with fuzzy matrixes based on the secondary criteria evaluations related to each main criterion, as follows (figure 4).

These steps were conducted for each supplier and afterwards, the following values were obtained accordingly (figure 6).

$$R_1 = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 2/3 & 1/3 & 0 & 0 \end{bmatrix} \qquad R_2 = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{bmatrix}$$

$$R_3 = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{bmatrix} \qquad R_4 = \begin{bmatrix} 2/3 & 1/3 & 0 & 0 \\ 1/3 & 2/3 & 0 & 0 \\ 1/3 & 1/3 & 1/3 & 0 \end{bmatrix}$$

Figure 3. The normalized matrixes of the first supplier evaluation

$$B_{11} = R \cdot u^T = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 2/3 & 1/3 & 0 & 0 \end{bmatrix} \bullet \begin{bmatrix} 1 \\ 0.8 \\ 0.6 \\ 0.1 \end{bmatrix} = \begin{bmatrix} 0.8 \\ 0.8 \\ 0.933 \end{bmatrix}$$

$$B_{12} = \begin{bmatrix} 0.8 \\ 0.8 \end{bmatrix} \qquad B_{13} = \begin{bmatrix} 0.8 \\ 0.8 \\ 0.8 \end{bmatrix} \qquad B_{14} = \begin{bmatrix} 0.933 \\ 0.867 \\ 0.8 \end{bmatrix}$$

Figure 4. Fuzzy comprehensive matrixes of the first supplier

$$U_{11} = A_{11} \cdot B_{11} = (0.549, 0.309, 0.142) \cdot \begin{bmatrix} 0.8 \\ 0.8 \\ 0.933 \end{bmatrix} = 0.819$$

$$U_{12} = A_{12} \cdot B_{12} = (0.878, 0.122) \cdot \begin{bmatrix} 0.8 \\ 0.8 \end{bmatrix} = 0.8$$

$$U_{13} = A_{13} \cdot B_{13} = (0.171, 0.618, 0.211) \cdot \begin{bmatrix} 0.8 \\ 0.8 \\ 0.8 \end{bmatrix} = 0.8$$

$$U_{14} = A_{14} \cdot B_{14} = (0.110, 0.434, 0.456) \cdot \begin{bmatrix} 0.933 \\ 0.867 \\ 0.8 \end{bmatrix} = 0.844$$

Figure 5. Comprehensive membership degrees of the factors considering the first supplier

$$U_1 = (0.169, 0.158, 0.165, 0.507) \cdot \begin{bmatrix} 0.819 \\ 0.8 \\ 0.8 \\ 0.844 \end{bmatrix} = 0.825$$

$$U_2 = (0.169, 0.158, 0.165, 0.507) \cdot \begin{bmatrix} 0.637 \\ 0.713 \\ 0.669 \\ 0.448 \end{bmatrix} = 0.558$$

$$U_3 = (0.169, 0.159, 0.165, 0.507) \cdot \begin{bmatrix} 0.679 \\ 0.859 \\ 0.853 \\ 0.792 \end{bmatrix} = 0.793$$

Figure 6. Comprehensive membership degrees of the factors for all the suppliers analyzed

(6) Suppliers are compared, sequenced and listed in table 3, depending upon the calculations above. According to the maximum membership principle, the first supplier evaluated, due to the highest membership degree, becomes included in the evaluation expression set member of "Excellent". Considering the calculations based on the evaluation factors and the decisions of each expert, selecting the first supplier (Supplier-1) for the procurement of leather material would be the right approach.

CONCLUSION, REVIEW AND RECOMMENDATIONS

This study has focused on the supplier selection problem for the leather purchase in leather apparel production. In order to achieve this goal, primarily the hierarchy of the criteria that influences the supplier selection was defined, afterwards the purchasing executives of the company in which this study was carried out, were consulted and they were asked to evaluate the suppliers in frame of the predetermined criteria. On the purpose of data analysis, AHP method that allows analysing the problem by converting it to criteria hierarchy and FCE method that allows converting the thoughts of individuals to numeric data and evaluating all the criteria at the same time, were used.

In line with the notions and preferences of decision-makers, a number of implications have been inferenced for the supply chain management of the company. Accordingly, among the three companies that supply leather to the apparel company, it seems that the company named "Supplier-1" has the highest score (0.825). Therefore, it is understood that "Supplier-1" is the most preferred company in the frame of the criteria agreed by the purchasing executives and it is the most suitable supplier for the Orjin leather apparel company.

Through this study, it is proven that the combination of AHP and FCE methods can be adapted to the supplier selection problem. Logical and consistent results were obtained by combining the advantages of these both methods and the most suitable supplier was determined by the company's criteria. In particular, using FCE method allows all employees, who are responsible from purchasing, to participate in decision-making. Thus, all factors that influence the final decision were analysed in detail and there is no factor that was ignored.

Accepting this study as a starting point, more general inferences for the sector could be made by including more purchasing specialists from different companies in the same field in the evaluations carried out within the method. In addition, the combination of both methods utilized for different decision problems from different sectors could also make contributions to the literature.

According to the notions of managers who have an active role in the leather industry; while making the decision, previous experience and ideas of individuals are utilized in the purchasing process. Thus traditional methods are used. However, this situation can bring with undesired results in multi-criteria decision problems where more criteria should be reviewed such as purchase process and increases probability of making mistakes.

By ensuring implementation of mathematical methods effectively in decision-making process, and making and applying decisions in the light of the concrete data, it will be possible to prevent the losses due to bad decisions of the company by providing more objective, measurable, traceable and controlled decision making. In addition; while using these methods, getting the opinions of the employees and acting in a co-decision will increase the dedication of the employees to company and this situation may also allow development of a better organization.

Today's competitive conditions and economic and political problems that the countries are facing affect many industries; therefore the companies are required to be managed under difficult conditions. The companies in the leather industry, which is one of the industries affected by these conditions, should internalize a professional

management approach in order to be in a competitive position. Resorting to modern technology instead of traditional methods in management and supply chain operations of the leather companies, which are competing by R&D, innovation and technology in the field of their production activities, would be also one of the important tools to be successful and to be in leader position.

Table 3. The sequence of the suppliers based on the combination of AHP ve FCE

Sequence	Alternatives	Membership degree
1	Supplier-1	0.825
2	Supplier -3	0.793
3	Supplier -2	0.558

REFERENCES

1. Sundar, V.J., Raghavarao, J., Muralidharan, C., & Mandal, A.B., 2011, "Recovery and utilization of chromium- tanned proteinous wastes of leather making: A review", Critical Reviews in Environmental Science and Technology, Vol: 41(22), pp: 2048–2075.

2. Thanikaivelan, P., Rao, J.R. , Nair, B.U., & Ramasami, T., 2005, "Recent trends in leather making: Processes, problems, and pathways", Critical Reviews in Environmental Science and Technology, Vol: 35(1), pp: 37–79.

3. Beshah, B., Kitaw, D., & Gelan, M., 2013, "Workstation design in an Ethiopian small scale leather garment industry", Procedia - Social and Behavioral Sciences, Vol: 75, pp: 434-442.

4. Directorate General for Industry of Turkish Republic, 2010, "The sectors of textile, apparel, leather and leather products", Retrieved from http://www.sanayi.gov.tr/Files/Documents/tekstil_sektoru_raporu-14-16082010142717.pdf (Date accessed: 25.04.2016)

5. Mokhtari, M., Javanshir, H., Dolatabadi, M.K., Tashakori, L., & Madanchi, F., 2013, "Supplier selection in textile industry using fuzzy MADM", Research Journal of Applied Sciences, Engineering and Technology, Vol. 6(3), pp: 400-411.

6. Patton, W.E., 1997, "Individual and joint decision making in industrial vendor selection", Journal of Business Research, Vol: 38(2), pp: 115-122.

7. Turkish Exporters Assembly, 2015, "Territorial numbers in terms of sectors", Retrieved from http://www.tim.org.tr/tr/ihracat-ihracat-rakamlari-tablolar.html Date accessed: 22.05.2016)

8. Cheragni, S., Dadashzadeh, M. & Subramanian, M., 2004, "Critical success factors for supplier selection: An update", Journal of Applied Business Research, Vol: 20(2), pp: 91-108.

9. Karaarslan, N., 2008, "A Fuzzy decision support system to supplier capability analysis in manufacturing industry, (Unpublished doctoral dissertation)", Sakarya University, Institute of Science.

10. Arda, R., 2010, "Applying both fuzzy logic and linear programming in supplier selection", Master Thesis, Istanbul University, Institute of Social Sciences.

11. Bayrak, M.Y., Celebi N.& Taşkın H., 2007, "A fuzzy approach method for supplier selection", Production Planning & Control: The Management of Operations, Vol: 18(1), pp: 54-63

12. Kumar, D., Singh, J., Singh, O.P, & Seema., 2013, "A fuzzy logic based decision support system for the evaluation of suppliers in supply chain management practices", Mathematical and Computer Modelling, Vol: 57(11-12), pp: 2945-2960.

13. Ofluoglu, P. & Miran, B., 2014, "Supplier selection through fuzzy pair-wise comparison method: A case of Turkish clothing sector", Journal of Textiles and Engineer, Vol: 21(96), pp: 1-9.

14. Yang, C. & B. Chen., 2006, "Supplier selection using combined analytical hierarchy process and grey relational analysis", Journal of Manufacturing Technology Management, Vol: 17(7), pp: 926-941.

15. Liang, Z., Yang, K., Sun, Y., Yuan, J., Zhang, H., & Zhang, Z., 2006, "Decision support for choice optimal power generation projects: Fuzzy comprehensive evaluation model based on the electricity market", Energy Policy, Vol: 34(17), pp: 3359-3364.

16. Shao, C., 2009, "The implication of fuzzy comprehensive evaluation method in evaluating internal financial control of enterprise", International Business Research, Vol: 2(1), pp: 210-214.

17. Bochao, L., 2010, "Supply chain risk assessment based on AHP and Fuzzy Comprehensive Evaluation", Proceedings of International Conference on Management of e-Commerce and e-Government, pp: 317-322.

18. Zhijie, G., Jie, J., & Ping, L., 2010, "Design and application of evaluation model on technical innovation ability of SMEs based on AHP and FCE", Proceedings of the 7th International Conference on Innovation & Management, pp: 494-498.

19. Shi, S., Jiang, M., Liu, Y., & Li, R., 2012, "Risk assessment on falling from height based on AHP-fuzzy", Procedia Engineering, Vol: 45, pp: 112-118.

20. Xi, X. & Qin, Q., 2013, "Product quality evaluation system based on AHP fuzzy comprehensive evaluation", Journal of Industrial Engineering and Management, Vol: 6(1), pp: 356-366.

21. Yang, S. & Wang, R., 2013, "Research on power coal supplier selection based on AHP and fuzzy comprehensive evaluation method", Proceedings of International Conference on Advances in Social Science, Humanities, and Management, pp: 431-434.

22. Yuan, J., 2013, "Fuzzy comprehensive evaluation enterprise performance management model based on AHP", International Journal of Digital Content Technology and its Applications (JDCTA), Vol: 7(6), pp: 539-547.

23. Xiang, S. & Li, X., 2014, "The establishment of AHP-Fuzzy model for comprehensive evaluation of "city obesity" degree", Proceedings of International Conference on Computer Science and Electronic Technology, pp: 56-62.

24. Xiong, G., Chen, Y., Shang X., Sjamg, L., & Nyberg, T.R., 2014, "AHP fuzzy comprehensive method of supplier evaluation in social manufacturing mode", Proceeding of the 11th World Congress on Intelligent Control and Automation, pp. 3592-3597.

25. Zadeh, L. A., 1965, "Fuzzy Sets", Information and Control, Vol: 8(3), pp: 338-353.

26. Li, M., Du, Y., Wang, Q., Sun, C., Ling, X., Yu, B., Tu, J., Xiong, Y., 2015, "Risk assessment of supply chain for pharmaceutical excipients with AHP-fuzzy comprehensive evaluation", Drug Development and Industrial Pharmacy, Vol: 42(4), pp: 1-9.